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The Software Engineering Process Office (SEPO) was formed at the Naval Ocean Systems Center in late 1988. SEPO's charter is to improve the software development processes from a Level 1 on the Software Engineering Institute's (SEI) Maturity Model to a Level 3 and above. One major effort in attaining a Level 3 is the establishment of a centerwide software estimation process. This paper describes SEPO's methods and progress in establishing a software estimation process at NOSC and a brief description of the process.

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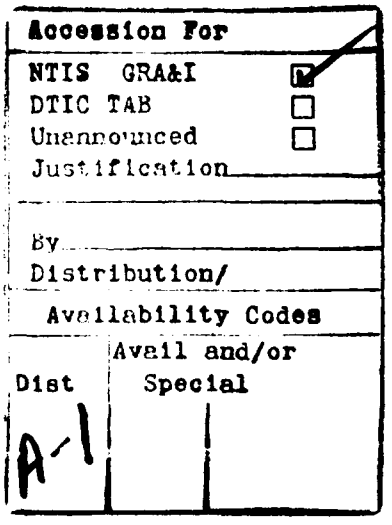

ESTABLISHING A FORMAL ESTIMATION PROCESS IN AN R&D ENVIRONMENT

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ABSTRACT - The Software Engineering Process Office (SEPO) was formed at the Naval Ocean Systems Center in late 1988. SEPO's charter is to improve the software development processes from a Level 1 on the Software Engineering Institute's (SEI) Maturity Model to a Level 3 and above. One major effort in attaining a Level 3 is the establishment of a centerwide software estimation process. This paper describes SEPO's methods and progress in establishing a software estimation process at NOSC and a brief description of the process.

Establishment of the Software Engineering Process Office - An assessment of the software engineering practices at the Naval Ocean Systems Center (NOSC), a U.S. Navy R&D laboratory, was conducted by the Software Engineering Institute (SEI) in early 1988 at the request of the NOSC Technical Director. The purpose of the assessment was to determine NOSC's level of maturity within the five levels of software maturity defined by SEI. The assessment determined that NOSC was a level one organization where one is the lowest level and five is the most mature level.

The summary report that SEI submitted to NOSC as a result of the assessment included nine recommmendations. The first and second recommendations were for NOSC to

- put into place formal procedures for estimating cost, size, schedule.
- establish a Software Engineering Process Group to serve as a focal point for software process improvement.

As a result of these recommendations the NOSC Software Engineering Process Office (SEPO) was formed in late 1988. SEPO's charter is to improve the software development processes from a level 1 on the SEI Maturity Model to a level 3 and above. SEPO became fully staffed in May 1989 with five full-time people and one rotator. The rotator is a person who transfers into SEPO from a line organization temporarily for a period of three months to one year and works as a resident member of SEPO.

Since its inception, SEPO has concentrated on establishing processes for software estimation, project tracking metrics, formal inspections, and software capability evaluations. SEPO has also established an Ada resource center and a repository of Computer Aided Software Engineering (CASE) data.

The NOSC Environment - NOSC is one of the Navy's primary Research and Development Laboratories. NOSC's primary mission is to develop and evaluate new technologies and implement new and improved C2, C3, ASW and Ocean Surveillance Systems. There are approximately 1600 engineers and scientists and at any one time there are 100 or more projects. Some of these are small one person, short duration projects while others are several billion dollars and span several years.

One of SEPO's first tasks was to determine how NOSC currently develops software. Any processes SEPO developed would have to address the current development methods. SEPO developed a survey that went to all the departments in NOSC. It was quickly determined that NOSC projects are conducted under various development approaches, e.g., waterfall, evolutionary acquisition, spiral and prototyping. Many projects utilize a standard waterfall type approach under delivery order or task order contracts. It was also determined that there is considerable emphasis on prototyping.

Software Cost Estimation Tools at NOSC - Some of the questions on the survey dealt with estimation practices currently in place. Most projects admitted that they did not use any formal method to estimate size, cost or schedule. The methods used to implement estimation practices include disseminating information about estimation tools, establishment of the Cost/Size/Schedule Estimation Process Working Group (CEPWG), sponsoring occasional one day, on-site symposiums for estimation tools, and some management mandated SEPO involvement in key projects.

One of the first things SEPO did to introduce NOSC software project personnel to estimation practices and methods was to hold a one day symposium on cost models. Five estimation tools were available for hands-on demonstrations: three commercially available tools; a public domain version of COCOMO (COnstructive COst MOdel); and a Navy/Air Force sponsored tool available to DoD agencies. The vendors of the commercial tools also gave presentations on their tools.

Because of the high level of interest at the symposium SEPO went ahead and obtained three tools, REVIC (REVised Intermediate COCOMO), SEER (System Evaluation and Estimation Resources), SASET (Software Architecture, Sizing, and Estimating Tool). REVIC is a public domain tool developed by Air Force Major Ray Kile as part of his reserve duties. SEER was developed by Galorath Associates, Inc. and utilizes estimation algorithms developed by Dr. Randall Jensen of Hughes. SASET was developed by Martin Marietta Denver Aerospace Corporation under contract to the Navy Cost Analysis Center. The SASET tool and training are provided free to DoD agencies.

REVIC was obtained because it was a good implementation of the popular COCOMO. COCOMO is the best documented estimation model and is used extensively throughout the United States and Europe. SASET was obtained because, in addition to being a good comprehensive tool, it was developed for the DoD and the price was right. SEER was selected because it is a good non-COCOMO, commercially available tool.

Since that time, SEPO has been able to acquire site licenses for two additional tools, SLIM (Software Life Cycle Management) and SoftCost-Ada. A large project conducted jointly by NOSC and the Naval Underwater Systems Center (NUSC) decided to utilize SLIM and SoftCost-Ada because they were already used at NUSC. The projects made the tools available to SEPO who in turn have made them available throughout NOSC.

Cost/Size/Schedule Estimation Working Group (CEPWG) - The role of SEPO is that of facilitator, i.e., to help project personnel acquire the skills and learning necessary to improve the processes within their projects and organizations. The most effective method of disseminating information about estimation methods, practices and

tools has been the working group which in reality has evolved into a regularly scheduled workshop. To date 15 CEPWG meetings have been held. Meetings are held every six weeks with an average attendance of 12-15 people. Since the first meeting in November 1989 over 75 people have attended at least one meeting.

Initially the attendance was limited to NOSC personnel. After much discussion however, it was decided to allow NOSC contractors to attend. The attendance is usually divided equally between NOSC personnel and contractors. The meetings usually consist of one or two presenters who address their project estimation experiences. However, the meetings do not always focus on estimation. A recent meeting featured a guest speaker who had attended the San Antonio I Meeting in January 1991. He addressed the efforts by the Joint Logistics Commanders in the revision of MIL-STD-2167A and -2168 as well as other military standards.

CEPWG Project Related Topics of Discussion - Guest presenters usually consist of project personnel who describe their use of the estimation tools on specific projects. They discuss their approaches, assumptions, problems and results. They also discuss their level of confidence, before and after, in the tool(s) that they used. SEPO personnel also provide overviews of how an estimate was developed for specific projects along with demos and discussions of how models may treat some aspect of the software development environment. Summaries of some of the presentations to date follow.

REVIC for Three Small Delivery Order Projects - This presentation addressed use of REVIC for estimating software developed under task order or delivery order contracts. This presentation brought some key issues to the surface. The most prevalent issue was how government agencies often have a pre-defined amount of money and need a new software package or a modification to an existing package. The contractors sign up for the work for the funding available because if they don't, somebody else will. It was generally agreed that contractors often resort to uncompensated overtime to get the job done. It was also agreed that these types of projects seldom follow formal documentation standards, good configuration management practices or have a quality assurance plan.

REVIC/SEER for Alternative Program Development Options - The application of the REVIC and SEER estimation models to evaluate cost tradeoffs of program options for a next generation wargamming system was presented. Four basic program options were under consideration, with each major option having a couple of sub-options. The options included various degrees of new code development vs. use of existing code on new platforms, and the impact of bringing in a contractor unfamiliar with the project. The presenter expressed concern in getting the models to converge on an estimate. However, he emphasized how the use of the models provided a credible basis of relative comparison of the cost impacts of the various options.

SASET Function Based Estimate - This presentation highlighted the use of two models to derive an estimate for a project in the concept exploration phase. Since this project was in the concept exploration phase, a well defined set of requirements was not available. To establish a rough estimate of size (source lines of code), the SASET model's historical data base was queried for functions similar to those that were to be developed. The resultant size was used to develop estimates with SASET and REVIC. The estimates reflected different levels of Ada programming experience and different levels of requirements volatility. Estimates showed potential costs of $7M to $11M (see table 1) vs. the project manager's original estimate of $700K.

TABLE 1

TECHNOLOGY DEMONSTRATION PROJECT
Data Fusion/Neural Net/Quick Response

PRELIMINARY ESTIMATES

SCENARIO		SASET	REVIC
Ada Exp	Reqs Vol		
Y	N	$8.8M	$7.3M
Y	VH	9.9M	10.0M
VL	N	8.9M	8.3M
VL	VH	10.4M	11.4M

Recode Pascal/FORTRAN to C & Rehost + Metrics Plan - This presentation provided an overview of the metrics plan for the project to recode Pascal/FORTRAN code to C and rehost it from a UNIVAC 1100 to an Intel HyperCube (IPSC/860 Touchstone). Also discussed was the use of REVIC to evaluate the cost of the project. The project plans to use an on-line distributed defect tracking system to track two major categories: How Was Personnel Time Spent; and Which Program Was Worked On. The presenter highlighted how the REVIC model had produced an estimate very close to the manual estimate derived by the project leader. The project leader agreed that using the estimation model was helpful and planned to learn one of the more comprehensive models soon.

Recode CMS-2 to Ada & Rehost - A contractor described how he had applied REVIC to a prototyping project. His first REVIC estimate was almost 150% higher than the effort actually expended. However, after re-evaluating the values of the environmental parameters and also obtaining a truer picture of the number of manhours per month actually expended per person, REVIC came very close to the actual. Also, the project manager

had originally set the REVIC parameter values too conservatively.

An EXCEL spreadsheet program was used to perform risk analysis based on the REVIC parameters. The spreadsheet allowed the user to vary any of the parameters and then observe the resultant sensitivity to cost. The contractor stated that he felt pretty comfortable with REVIC now and plans to use it for future software project estimates. One of the primary benefits he felt was the visibility the model gave him into the effects of the development environment, vs. just the size, on project costs and schedule.

REVIC/SoftCost-Ada for One Man Ada Project - A NOSC software engineer described his use of REVIC and SoftCost-Ada to develop cost and schedule estimates for a small project estimated to be 2,900 Ada lines of code (LOC). He described how he doubled his size estimates to get around SoftCost-Ada's minimum size requirement of 5,000 LOC. Then by applying the power curve, he arrived at an estimate he could divide by two. Since the REVIC results were consistently higher by the same degree than the SoftCost-Ada results, he felt comfortable using the combined results of the two models to arrive at his project's estimates.

Basic Estimation Metrics Tracking - SEPO has presented a format to collect basic cost tracking information. The Project Estimate History Tracking Form, available on e-mail, provides a simple format to record the original cost, size and schedule estimates, and the actuals during the project life cycle. The feedback on the form will help to establish a NOSC project cost historical data base. The format consists of the following information

- Basic project information
- Estimation method
- Milestone dates
- Estimated CSCIs/CSCs vs. actuals
- Original new SLOC estimates vs. revised estimates and actuals
- Original reused SLOC estimates vs. revised estimates and actuals
- Original cost and schedule estimates vs. revised estimates
- Original estimated page counts vs. revised and actuals

CEPWG Topics Related to Cost Model Parameters - There is as much interest in the generic issues of software estimation as in specific project experience. In addition to project related presentations such as those outlined above, presentations often address cost related issues in general: the differences in specific models; the variation of parameters from model to model; highlights of cost related conferences; demonstrations of models are provided; as well as presentations dealing with theory such as Halstead's metrics.

Some of the specific topics to date have included impact of changing schedules on cost; uncompensated overtime vs. cost/schedule; cost of documentation; impact of design for reuse; basic cost risk tradeoffs; cost of CASE tools; and multiple CSCIs vs. one large CSCI. Many discussions have revolved around the merits and disadvantages of specific tools. The use of estimation tools has been very effective in demonstrating areas of high cost and schedule risk, e.g., the severe impact that code growth can have on a project's development cost. The discussions and demonstrations of tools have shown how the aggregation of two or more erroneous assessments early in the project can have disastrous effects on a project. One recent example demonstrated the cost risk when estimates of size and experience were both overestimated (figure 1.)

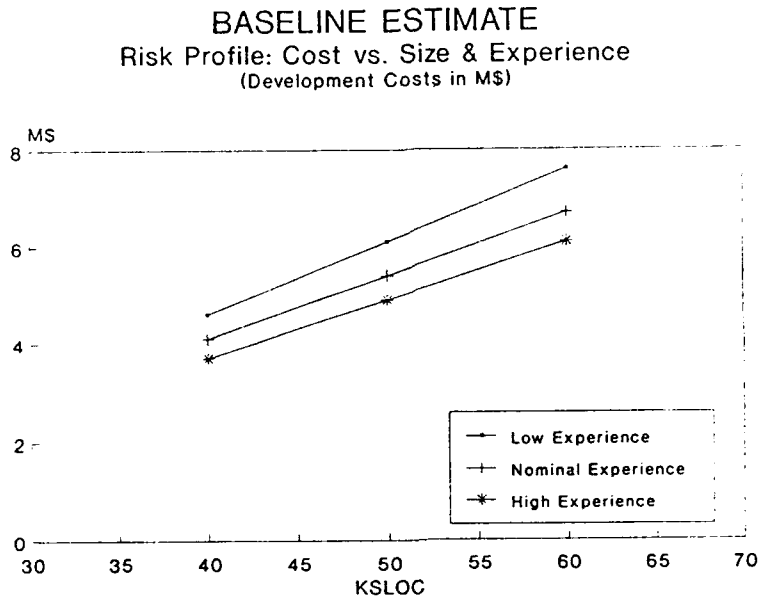

Figure 1. Risk Profile of Cost vs. Size and Experience

Introducing Projects To the Process - The establishment of a formal estimation process has been a primary SEPO activity for two years. The basic process itself can easily be stated in a few words: develop a size estimate based on experience; use the size estimate to derive cost and schedule estimates; track the actuals and periodically revise the estimates. However, establishing the process is not as easy. There is always resistance to change as well as inertia. People are slow to adopt new methods and ideas, even when they believe in them. Establishing the process has consisted of three primary steps; provide personnel with a quick overview of the process; give them a quick tutorial of an estimation tool; and provide follow-up support.

The estimation process consists of the three basic steps summarized above. These steps are elaborated upon during the initial meeting with project personnel. Elaboration of these steps provides project personnel with the basics of how to develop initial estimates and track the estimates vs. actuals. The basic process of developing an estimate is summarized in figure 2.

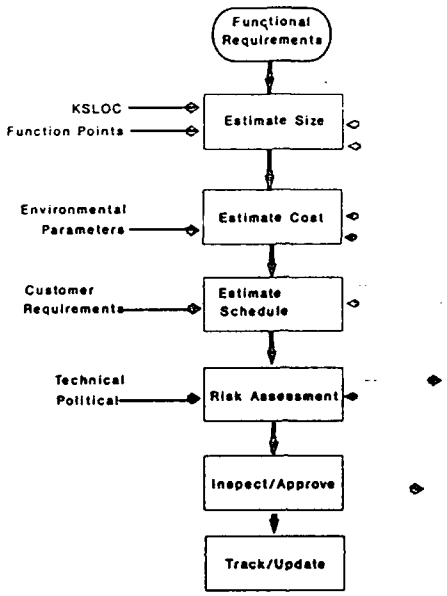

Figure 2. Summary of Software Estimation Process

The process shown in figure 2 is expanded during the initial meeting to include the following points

- Develop a Work Breakdown Structure early
- Estimates should be developed by two or more people
- Two methods of estimation should be used
- Develop a range of estimates, low, most likely and high
- Inspect/review the estimates
- Track and update

Software Estimation File - One of the key elements of the process includes establishment of a Software Estimation File (SEF). This, very simply, is the documentation and retention of the work that goes into and affects the estimates. It is more than just updating the Software Development Plan. The SEF contains any information affecting the estimates as well as the estimates themselves. The SEF contains cost related metrics tracking data and records of cost risk analyses. The contents of the SEF and their organization is shown in Table 2.

TABLE 2

Software Estimate File Format

TABS	CONTENTS
Project Data	Description of Project - Application, Language, Sponsor Mode of Development - Schedules
Memos	Copies of Relative Material - Basis for Size Estimates - Schedule Alterations - Project Redirection
Summaries	Summary Sheets of All Formal Estimates - Basic Assumptions - Critical Parameters - Models Utilized
History	Detailed Info on All Formal Estimates - Input Data - Printouts of Models

Familiarization with Estimation Tools - Project personnel receive a short tutorial, approximately 30 minutes, of REVIC. A sample estimate is developed using available project data and then "what if" games are played to demonstrate areas of high cost and schedule risk potential. Project personnel always receive a copy of the REVIC and supporting documentation.

A second estimation model is demonstrated if time allows and attention spans have not withered. Emphasis is placed on the similarities and differences between the models. A project estimate is generated with the second model and differences between the models are discussed.

Follow-Up - The importance of tracking the initial estimates and developing revised estimates is stressed. Initial project estimates are often never seen nor referred to again. This is the result of not documenting the estimates and supporting data in a formal manner. Initial estimates should be constantly reviewed and revised estimates generated whenever there is any change in direction. New estimates should be developed at least monthly and prior to all major program reviews, i.e., PDRs, CDRs, etc.

Follow-up support is provided by the Software Quality Assurance Branch or by SEPO. Projects will generally prefer continued support by SEPO since SEPO does not charge directly for their services. However, SEPO does not have the staff to perform continued support. It is emphasized to the projects that SEPO's role is that of facilitator.

Observations of People Using Cost Models for the First Time - People are usually receptive to cost models the first time they use them. They like the ease-of-use afforded by the models and especially how easy it is to play "what if" games. People are usually impressed by

the many factors included in the models. The initial estimates developed during the tutorials are often disclaimed as being "way too high." However, even if the estimates are much higher than anticipated (cost sometimes 2 to 3 times higher and schedule up to 50% higher) they often admit that they had not considered all of the factors contained in the model's environment.

After people receive an introduction to a model however, they sometimes skew the environmental parameters to get the desired answer. Common errors include overestimated staff capabilities and experience, too much faith in CASE, and underestimating the size. A common error also related to size is the underestimation of the effort to convert existing code. The conversion of existing code is almost never as trivial as initial assessments had assumed.

Common errors observed when using REVIC include not selecting the correct mode, i.e., embedded, semi-detached or organic. People often select a mode that suggests a more complex project than their project warrants. Also, people do not allow for reduced documentation, configuration management and quality assurance requirements when estimating prototype projects.

Conclusion - To date, SEPO has provided estimation assistance to over 30 projects. This experience has helped to highlight key elements that must be included in a formal estimation process. The working group has been the most effective method of disseminating information on the software estimating process. The NOSC software engineers and NOSC contractors contribute equally to the discussions. Likewise, both factions are receptive to new estimation methods and tools to increase the accuracy and credibility of their estimates.

Major progress has been made in developing credible estimates through the use of estimation tools. The tool used most often is REVIC, a public domain computer program that utilizes the well documented COCOMO cost/schedule estimation algorithms. REVIC is used more than other models because an estimate can be easily generated in a few minutes.

More comprehensive models provide more input and output options but take more time to master. Experience to date indicates most project leaders do estimates because they have an immediate requirement. Once the requirement is satisfied, the tool is not used until the next estimate is absolutely necessary. Then, project managers again want an easy-to-use tool, assuming its results are credible. One of the goals of establishing an estimation process is to move estimates from the realm of "fire drills" to a routine and periodic exercise.

Progress to date has been substantial but there is still a long way to go in making formal estimation processes an automatic part of every project. The instantiation of the process described here will hopefully contribute to increasing the credibility of proposed project costs and schedules.